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Mackenzie Delta-Beaufort Sea

A Geological Interpretation and Investment Approach

HIGHLIGHTS

- The Mackenzie Delta will be the first domestic frontier region to see both oil and gas development.
- Through PetroCanada, the Canadian government is expected to play a major and direct role in petroleum development of this area.
- The highest potential for discovery is in the deeper Tertiary and Cretaceous sedimentary deposits. These formations, as shown on the enclosed **Geological Map**, have combined thicknesses of up to 20,000 feet.
- In the immediate Richards Island and Beaufort Sea area, ultimate recoverable reserves are estimated at 10 billion barrels of oil and 100 trillion cubic feet of natural gas.
- The prime locations in the Mackenzie Delta, as shown on the enclosed **Land Ownership Map**, are held by Imperial Oil, Shell Canada, Gulf Canada and Dome Petroleum.
- The major producing companies not represented in this domestic frontier region will have difficulty replacing declining conventional production.
- As a result of expected problems in acquiring attractive acreage positions in the Delta, investment within the Canadian petroleum industry must emphasize those companies currently having the best exposure in this region.

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INTRODUCTION

With the realization that petroleum production from conventional Canadian sources will eventually decline and that frontier sources will have to be developed, there is a growing concentration on the analysis of the Mackenzie Delta region. There is little doubt that this area will be the first frontier region to be developed: the exploration program to date has probably discovered close to the minimum threshold volumes (including proven and probable reserves) for natural gas – about 15 trillion cubic feet – and is rapidly approaching the two billion barrels necessary to justify an oil pipeline. An application has already been submitted to the National Energy Board to build a natural gas pipeline from this area to southern markets, and the federal government appears to be ready to support this development. An oil pipeline submission can also be expected shortly.

While drilling activity has shown definite declines in the conventional regions of Canada, overall interest has increased considerably in the Delta. It is because of this growing exploration interest and the imminence of a transport facility that a geological analysis of the whole region is necessary. (Appendices I and II are detailed analysis of the geology, tectonics and deposition of the area.) A logical extension of such a study is an assessment of company holdings in the region. (Appendix III includes a listing and rating of the holdings for most of these companies.)

To assist in the evaluation of both the area and the individual company acreages, a detailed regional **Geological Map** of the Delta and surrounding area has been prepared. This map is the result of researching geological studies and integrating gravity and magnetics data obtained from the federal government. As well, certain seismic reflection data on the Tuktoyaktuk Peninsula and east of Herschel Island in the Beaufort Sea has been incorporated. A section of this report (Page 7–8) deals primarily with how to read and interpret the **Geological Map**.

Gravity data used to develop the regional subsurface structures consists mainly of information gathered from land and ice stations generally spaced throughout the area on a 4-5 mile grid. The current phase of exploration appears to be based primarily on structural considerations. As development continues, information gained may very well point to areas where significant stratigraphic entrapment may have occurred.

A second map has also been prepared outlining the holdings of the various companies in the area. This **Land Ownership Map** is of the same scale as and a complement to the **Geological Map**.

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SUMMARY

Information received to date from seismic interpretation and drilling results clearly indicates the potential for significant hydrocarbon deposits in the Mackenzie Delta region. While estimates of hydrocarbon potential vary, we estimate that the Richards Island and Beaufort Sea region has an ultimate potential of approximately 10 billion barrels of oil and 100 trillion cubic feet of natural gas. The most attractive potential may very well be associated with the diapiric structures in the Beaufort Sea. Complementing these are Tertiary and Cretaceous sedimentary deposits up to 20,000 feet in thickness.

Although several of the industry participants have acreage positions that could produce enormous reserves of natural gas and oil, an element of caution must be exercised in translating this into profit potential for the various companies. There are likely to be constraints that will limit the absolute level of reserves that may reasonably be assigned to each company.

The ultimate annual and lifetime capacity of future Delta pipelines (both oil and gas) will limit the individual company's realistic throughput. For example, if a natural gas pipeline has an ultimate throughput of 20 trillion cubic feet, then any company with proven Delta reserves in excess of 20 trillion cubic feet would have more reserves than should be discounted. Eventually what will happen is that the region will have prorationed production. While Imperial Oil, Gulf Canada and Shell Canada and their associated operating partners have virtually all of the proven Delta reserves to date, any further discoveries made by other companies will reduce the input of these three. The difficulty in quantifying the potential is in trying to determine what will be the realistic ultimate input and therefore, the measureable reserves of each company.

The recent submission by Imperial, Gulf and Shell to the federal government of an application to construct a Mackenzie Delta natural gas gathering and processing system gives some indication of the total throughput of natural gas that these companies will have. At this time, it can be assumed that each of them will initially have an **equal input** to a natural gas pipeline. As a group, they could well represent 50%-70% of this pipeline's capacity.

It is difficult at this time to develop the same analysis for crude oil potential because there have been few discoveries and because little information is available on those that have been made. At this stage, it appears that there will be an **unequal input** to an oil line – Imperial Oil will likely have the largest production volume, followed by Shell and Gulf.

However, while there is considerable potential for petroleum development in the Mackenzie Delta, it must be emphasized that not all companies have holdings there. The federal government will likely become directly involved in the oil industry through PetroCanada and most of the Crown acreage in Mackenzie Delta may therefore remain with it. This will make it difficult for those companies not already in the region to obtain economically attractive positions through which they can expect to replace declines to conventional reserves and production.

THE MACKENZIE DELTA – PETROLEUM INDUSTRY

During 1973 and 1974, two major factors affected the development of the Canadian petroleum industry:

1. The magnitude and frequency of changes in petroleum production regulations, taxes, royalties, etc., introduced and implemented by both the provincial and federal government. Aggravating this situation was the federal-provincial battle over taxation control of the industry.

2. The realization that oil and gas, as finite resources, will eventually show declines in conventional reserves and production. The beginning of this phase of the industry's life began during 1974 and will become even more pronounced until a new region is developed. Thus this decline in production could very well continue until the early 1980's. By that time, a natural gas and/or oil pipeline from the Delta will probably be on stream.

Because Western Canada's conventional petroleum production and reserves are declining, the replacement potential of the Delta has become even more important. Since applications have already been submitted to the National Energy Board, it would appear that a natural gas pipeline from the Delta will precede an oil line. However, an oil line will likely follow within a few years. While an evaluation of a company's replacement potential is important, consideration must still be given to an analysis of both its current operations and its ability to generate production profits.

There are basically three ways in which production income can be increased:

1. higher production volumes,
2. net price increases,
3. lowering of provincial royalties and federal taxes.

However, as previously mentioned, production from conventional sources is already in a decline. Net unit price increases are likely in 1975 and modifications in provincial royalties and federal taxes are also expected. However, to be effective, the combination of net price increases and lower taxes/royalties must be at a greater rate than the rate of decline in production. While this will occur in 1975, it will not continue through 1976 and beyond.

In light of current production declines, the expected changes to net prices, and the uncertain political environment, **investment consideration in the industry must now emphasize oil and gas replacement potential.** The prime criterion for investing in the Canadian oil and gas industry is still to select those companies whose current conventional production and frontier acreage afford the opportunity of increasing both reserves and production. Investment should be concentrated on those companies whose replacement potential exceeds that of other companies with the same capabilities.

The ideal situation then would be a company with both good conventional acreage and production (with excess producible capacity) and high potential acreage holdings in the Delta; the company's stock price should reflect a conventional reserves asset value only. (In lieu of a Delta position, an equally promising holding in the offshore Gulf of Mexico would be acceptable.)

To better appreciate why the emphasis must be on current Delta acreage and not on the ability to get there, a careful examination of the three primary mechanisms for acquiring new positions is necessary. These are:

1. Successfully bidding on Crown acreage which is held for auction.
2. Outright acquisition of a company with positions in the region.
3. Taking a farm-out, etc., from a company holding acreage in the frontier region.

While these three alternatives are available at the provincial level, they may not be in federally-jurisdicted regions. Largely as a result of political problems, two new extraneous risk factors – PetroCanada and the Foreign Review Board – have evolved during the past two years. (Originally, the only risk faced by the industry was that associated with the expenditure of capital and the probability of finding a dry hole. This risk still remains but there are enough tools and skills available to make a sensible assessment of drilling locations and probability analysis for economic discovery.) At this time, it appears that the federal government intends to become directly involved in the petroleum industry through PetroCanada. And the Foreign Review Board is likely to exert tight control over foreign ownership within the petroleum industry.

The practice of giving up 50% of permit acreage (in a pre-defined pattern) to the Crown, in going to lease, will probably not change significantly. Other rules relating to work requirements, etc., are expected to change and will probably be reviewed on a continuing basis.

The major change most likely to take place will be related to the action taken by the federal government on the acreage handed over to it by the industry when going from permit to lease. The general feeling at this time is that these Crown-held lands be given to PetroCanada rather than being auctioned off. This Crown corporation then is expected to evaluate all its properties and probably contract drill those which appear to have the better prospects for hydrocarbon accumulation. After such evaluation, any properties not deemed to be high enough in petroleum potential will be either farmed-out or put up for auction. As a result, those companies not holding any exploration acreage in the Delta and wishing to acquire a position through the "auction-bidding" alternative will probably have to choose from third rate property at best. This may be fine for smaller junior situations, but a major producer trying to replace large volumes of production is unlikely to acquire suitable acreage in the Delta through this approach.

The second mechanism by which a Delta position can be obtained is through the outright acquisition of a company which already has good exposure there. However, there are two reasons why this is not a probable occurrence. First, there are only a few suitable take-over situations (generally juniors) with promising acreage in the area. As development becomes more imminent, the price of acquiring any of these situations will rise accordingly. Second, it is unlikely that the Foreign Review Board will allow an outright purchase of a junior oil company by a foreign-controlled company, especially if the junior is Canadian-owned. Because most of the major oil companies without a good position in the Delta are sufficiently foreign owned, it is likely that any acquisition will have to be reviewed by the Board. It should be noted here that while a foreign take-over of a Canadian company will not likely be allowed, it is possible that a foreign take-over of a foreign company will be permitted. Generally then the "acquisition" alternative will not be as available as in the past.

The most conventional means of acquiring an exploration position within the oil industry has involved taking some form of farm-out arrangement from a company which already has a position in the desired area. However, with most farm-outs, the farmor seldom discards what its geological analysis deems to be prime acreage. Most often it is the marginal acreage that is dealt away. And even with these poorer properties, the drilling agreements very seldom favour the farmee. Thus, while the "farm-in" alternative is still available, it will become less economically attractive for the farmee. As well, with the constraints surrounding expansion of Delta acreage holdings, there could even be some resistance by companies making farm-out acreage available.

It would appear, therefore, that the three alternative means of acquiring Delta positions are either not available or limited in economic viability. As a result, it is imperative that concentration be on those companies which **currently** have good Delta exposure.

The following section is an attempt to interpret the geology and hydrocarbon potential of the Delta region. It must be read in conjunction with the enclosed **Geological Map**. As previously mentioned, Appendix I and II should be used for a more detailed evaluation and analysis of the region and its potential.

THE MACKENZIE DELTA – GEOLOGY

The enclosed **Geological Map** shows a plan view of the Mackenzie Delta area with a corresponding **Diagrammatic Section**. The cross-section roughly follows the line A' to A which is shown on the map in a east to west direction. To simplify the interpretation of the area, the colour scheme used on the plan view of the map as well as in the **Diagrammatic Section** coincides with the geologic time periods shown on the legend. This cross-section has been extended to show Paleozoic carbonates outcropping to the east of the map border on the Anderson-Horton plain. This region is generally to the east of the Tuktoyaktuk Peninsula.

Following the cross-section from east to west, commencing at the A' location, the map actually begins where the Cretaceous sediments outcrop and indicate little build-up of any post-Paleozoic (i.e., Cretaceous and Tertiary) sediment under the plain. The potential for hydrocarbon accumulation increases within Cretaceous through Tertiary deposits as detailed in Appendix I, Page 11–12; this particular segment of the cross-section would appear to have a low probability for discovery. The two major fault lines shown on the **Diagrammatic Section** coincide approximately with the east and west shorelines of the Tuktoyaktuk Peninsula. These lines border a highly disturbed area of structural transition with considerable faulting throughout the whole Peninsula. The faults in this area, and elsewhere on the **Geological Map**, are shown as black lines with the direction of the down-dip given by an associated arrow.

Beneath the surface of the Peninsula is a build-up of 7,000-8,000 feet of Cretaceous sediments. As indicated on the corresponding part of the **Diagrammatic Section**, only a thin mantle of Tertiary sedimentation covers the Peninsula. Drilling in this region has been somewhat disappointing with Atkinson Point H-25 the only significant discovery to date. The highly-faulted nature of the region makes interpretation difficult and may be responsible for the relatively poor showing thus far.

Leaving the Peninsula and travelling west along the cross-section, it can be seen that the Tertiary and Cretaceous sedimentation builds towards the west and under the Beaufort Sea. The presence of Tertiary and Upper Cretaceous sediments having a combined thickness of up to 20,000 feet in the Mackenzie Delta area is extremely significant because it is the Tertiary sands that provide the major portion of the hydrocarbon reservoirs throughout the world. Undoubtedly these will provide a very significant portion of reservoirs to be found in the Beaufort Basin and Mackenzie Delta.

It can be seen that the highest potential for hydrocarbon accumulation lies west of the Early Paleozoic Carbonate Facies Front. To date, the most successful drilling has taken place on Richards Island, which overlays a considerable thickness of Tertiary sediments. The cross-section suggests a trend to thicker Cretaceous and Tertiary sediments westward under the Beaufort Sea.

Imperial Oil's Adgo F-28 oil and gas discovery, which was drilled on an artificial island off the west coast of Richards Island, confirms this trend towards increased hydrocarbon potential under the Beaufort Sea. For more affirmative confirmation, many more wells will have to be drilled in waters further out into the Beaufort Sea. Dome Petroleum plans to test such structures during the 1976 drilling season. Two drill ships will be required for the exploratory drilling program. The first exploratory well will be of considerable interest because it will test the potential for hydrocarbon reservoirs with the regional anticlinal and fault-induced structures developed to date on Richards Island. The structure where the first well is to be drilled appears to be about 20 miles long and 6 miles wide, with an indicated enclosure of approximately 2,000 feet. This is a high potential structure by any standard.

As shown on the **Diagrammatic Section**, there are indications of diapir development of shale or salt origin over a large area under the Beaufort Basin. The extent of this development is not defined on the map, but merely indicated in an arbitrary setting. There are indications that there are numerous dome-type structures and that the potential for finding hydrocarbon reservoirs in both the Cretaceous and Tertiary sediments is extremely high.

There are now two indications, which are clearly outlined on the Geological Map, that will require further exploratory drilling to determine the accuracy of the information:

1. The presence of the extremely thick Cretaceous and Tertiary sedimentary deposits with the high probability for hydrocarbon accumulation.
2. The existence of the diapir development or salt dome intrusions which occur throughout the area further enhancing the probability for hydrocarbon entrapment. (Dome Petroleum plans future tests of such structures in the Beaufort Sea.)

In order for potential oil and gas reservoirs to exist there must be some form of entrapment. Generally, there are two ways in which hydrocarbons may be trapped:

1. A structural entrapment, where hydrocarbons become trapped in an anticlinal or dome feature and/or where the reservoir continuity is interrupted by a fault (indicated by black lines on the **Geological Map**). Structural traps abound in this region.
2. A stratigraphic entrapment, where hydrocarbons are trapped in porous reservoirs that pinch out against impervious beds. This type of entrapment usually has a high potential.

The initial phase of exploration will concentrate on the seismically defined structural traps.

Anticlines are indicated on the **Geological Map** by red lines running along the crest of the anticline (structural highs), with arrows indicating the direction of fall-off on either side. It can be seen that most of the successes to date have been drilled along these indicated anticlines, which exist in association with indicated faults (black lines). These fault-induced structures are responsible for fields such as Taglu. The most significant anticlinal structure, also associated with a parallel fault, on Richards Island is the Tununuk High which extends well out into the Beaufort Sea. Seven discoveries have been recorded thus far along or in the vicinity of this structure. On the western extremity of this high are Imperial Oil's Adgo F-28 and P-25 oil and gas discoveries. Shell Canada has recorded significant natural gas discoveries at Niglintgak M-19 and H-30 and oil discoveries at Kumak J-06 and Kugpik 0-13. The group of Imperial Oil, Gulf Canada and Shell Canada have a joint interest in the Reindeer F-36 natural gas discovery also along the Tununuk High.

Directly north of Richards Island in the Beaufort Sea, the **Geological Map** indicates two anticlinal structures along with several fault blocks. These lines do not necessarily define the geology of the area, but are merely intended as an indication of a geological province roughly similar in size and structure to the Richards Island area. It is quite possible that whatever reserves are ultimately developed on Richards Island will be easily duplicated in the Beaufort Sea area. Full development of this region will require drilling, well into the 1990's. Ultimate recoverable reserves from within the Mackenzie Delta region could well be in excess of 10 billion barrels of oil and 100 trillion cubic feet of gas.

THE MACKENZIE DELTA – LAND HOLDINGS

The **Land Ownership Map**, outlining the permit holdings of the various companies in the Delta region, uses the same scale as the **Geological Map**. It is clear that any land ownership map does not give any indication of the potential that is associated with the acreage held by the participating companies. Similarly, a geological map cannot provide details regarding those companies that have positions where the probability for discoveries is high. Thus for a valid interpretive analysis, it is necessary to study both maps.

A study of the two maps clearly indicates those companies that appear to be best represented in the Mackenzie Delta-Beaufort Sea region. Because there is no Land Act as yet, although one is expected by early summer 1975, the permit holdings rather than lease positions (for those where a

company went to lease) are shown on the **Land Ownership Map**. It is possible that a revision to the disposal of land process may alter present lease holdings.

Imperial Oil holds the largest permit acreage position in the whole region. (Imperial has gone to lease on certain of its onshore positions – these are not indicated on the **Land Ownership Map.**) By studying our two maps, it becomes apparent that the company also holds the most promising acreage. This includes land holdings on both Richards Island and in the Beaufort Sea. The company has already recorded significant discoveries at Atkinson Point, Mayogiak, Ivik, Mallik, Taglu and Adgo. Also, in conjunction with Gulf and Shell, it has drilled successful wells at Titalik and Reindeer. As can be seen on the **Geological Map**, each of these discoveries was made on or near an anticline (red line) associated with a fault line (black line).

Estimates of oil and gas reserves are shown on the **Geological Map** where sufficient information is available. The two most obvious omissions are Imperial Oil's Adgo and Shell's Niglintgak discoveries. Possibly upon completion of the Adgo P-25 and Adgo C-15, sufficient information will be available to arrive at a reasonable estimate. It must be noted that a good part of Imperial Oil's holdings are spread over the Tuktoyaktuk Peninsula. As indicated in a previous section, this area is highly faulted with relatively thin Tertiary and Cretaceous deposits. Drilling results to date in this area have supported this interpretation. This also is the area where Imperial Oil has farmed out much of its position to other companies. The terms of these farmouts appear to favour Imperial Oil.

In terms of Delta Acreage and its ultimate potential, Gulf Canada should be ranked number two. The prime difference between Gulf and Shell is that Gulf has what appears to be very attractive offshore Beaufort Sea acreage. Combining this with its onshore Richards Island holdings, the company would have to rank above Shell, but certainly second to Imperial. Gulf Canada has participated in several significant discoveries such as Parson's Lake and Ya Ya. It also has an interest in the Titalik and Reindeer natural gas discoveries.

With its excellent onshore acreage – especially along the Tununuk High – Shell Canada is ranked close behind Gulf. However, the company lacks a position in the Beaufort Sea. Shell's recent Niglintgak M-19 natural gas discovery, a follow-up to the Niglintgak M-30 discovery, is proving up a field that could have production capabilities of up to 500 million cubic feet per day. The field is also proving to be a potentially significant oil discovery. The company also has oil discoveries at Kugpik 0-13 and Kumak J-06 and is sharing in the Titalik and Reindeer discoveries.

Dome Petroleum is the only major producing company with exposure throughout the area. Although the company's onshore acreage positions would appear to be low in potential, its offshore holdings are excellent. Besides its own acreage, Dome can earn positions in other properties (as shown on the **Land Ownership Map**) throughout the Beaufort Sea by the drilling of wells. The first two are expected to be drilled in mid-1976. Both wells will probably be on structures with thick Tertiary and Cretaceous sediments. These will be two of the most interesting wells drilled in the Mackenzie Delta.

Although Dome has yet to participate in a discovery, its offshore acreage is of sufficient quality to rank the company's ultimate absolute reserves potential as fourth best in the area. With the possible exception of Canadian Superior, there are really no other **major** producers with a position of this quality in the region.

The fifth position then must be shared by a number of firms having several small, but nonetheless good, holdings. In this group are Numac Oil and Gas, Canadian Export Oil and Gas, Scurry Rainbow (Home Oil), Sun Oil, Bow Valley as well as Canadian Superior.

APPENDIX I

DETAILED GEOLOGICAL INTERPRETATION

STRATIGRAPHY

The Mackenzie Delta is bordered to the west, south, and east by outcrops of the various formations present in its subsurface.

PALEOZOIC – Indicated by Pink on the **Geological Map**.

(i) **Precambrian**

Sediments of Precambrian age occur to the west in the British Mountains where the Neruokpuk Formation is exposed. The Neruokpuk Formation is composed of a thick section of phylite and cherty limestones, which range in age from Late Precambrian to Middle Devonian. This section is not differentiated as to age and is indicated on the map as PE-Sn.

Precambrian sediments are also present on the east side of the map area and on the southern tip of Banks Island.

(ii) **Cambrian**

The Cambrian is present throughout the eastern portion of the map area where it is composed of 300-500 feet of sand and shale of the Mount Clark and Mount Cap Formations overlain by about 500 feet of Saline River Formation. Not shown on the **Geological Map** – but directly south – is the Saline River which is composed of an evaporitic sequence with evidence of thick salt present in the Norman Wells area. This evaporitic basin may extend across the map area and provide the source material for numerous diapiric type structures evident on seismic throughout Beaufort Basin.

(iii) **Ordovician-Silurian-Middle Devonian**

This group of formations is represented in the area by two distinct facies. To the east of the Tuktoyaktuk Peninsula, thick carbonates, termed the Ronning Formation, are overlain by carbonates and evaporites of the Middle Devonian Bear Rock Formation. Along the western boundary of the Tuktoyaktuk Peninsula, a facies change is interpreted where the carbonates are replaced westward by thick off-reef shales and argillaceous limestones of the Road River and Prongs Creek Formations. Should this carbonate facies front exist, hydrocarbon reservoirs of considerable extent may occur along this boundary under favourable structural conditions.

(iv) **Upper Devonian – Imperial Formation**

The Upper Devonian, where present, is composed of a lower marine shale sequence termed the Canol Formation, overlain by non-marine sands and shales of the Imperial Formation. These beds have been truncated from west to east by the pre-Cretaceous unconformity exposing the subcrop edge to the south of the Tuktoyaktuk Peninsula. This Formation has not yet been encountered in the subsurface of the Delta.

(v) **Carboniferous**

Beds of Carboniferous age are present within the British Mountains and south of the map area in the Dave Lord Ridge area (67 degrees N, 139 degrees W.) where shales of the Kayak Formation and carbonates of the Lisburne Group outcrop. Carboniferous beds are not expected to continue under the Delta, but may be present in the northwestern portion of the map area under the Beaufort Sea.

CRETACEOUS – TRIASSIC – Indicated by Green on the **Geological Map.**

(i) **Permian – Triassic**

Thin Permian and Triassic beds have been encountered in the subsurface under the western reaches of the Delta and consist predominantly of shales and poorly developed sandstones. These beds are postulated to extend and thicken northward under the Beaufort Sea where thick porous reservoir sands, similar to the productive horizons of Alaska, may occur.

(ii) **Jurassic**

Thick Jurassic beds occur throughout the western portion of the map area, but only extend a short distance into the Interior Plains. Upwards of 4,000 feet of dark grey to black shale with interbeds of siltstone outcrop in the British Mountains. Relatively thick marine sandstones of the Bug Creek Formation have been encountered in the southern portion of the Delta. These sands, which range from 200 feet to 500 feet in thickness, are considered to have good hydrocarbon potential in areas where favourable structural conditions combine with increased porosity development.

(iii) **Lower Cretaceous**

Thick lower Cretaceous clastics were deposited under the Delta and in the Richardson trough to the west. These beds range from 4,500 feet in thickness in the Parsons Lake area to 14,000 feet in outcrops to the west of the Delta.

Well developed sandstones (Parsons Sandstone) of Delta distributary origin occur in the lower 1,000 feet and provide the reservoirs for the Parsons Lake Field. Gas pays average approximately 300 feet in the Parsons Lake Field.

Accumulations in the Parsons Lake area are associated with closures along fault structures. Pool sizes appear to be limited by the length of the faults and the amount of closure created by them. Structures west of the Eskimo Lakes Fault System appear to be of sufficient areal extent to provide fields with significant reserves. East of the Eskimo Lakes Fault System, a multitude of faults and tilted fault blocks are present over the Tuktoyaktuk Peninsula. To date the number of successes within these structures on the Peninsula is disappointing and many of these features are yet to be tested. It is likely that this region will be further explored and developed once the Delta becomes a mature producing province and economics justify the development of these smaller fields.

(iv) **Upper Cretaceous**

Beds of Upper Cretaceous age are present throughout the Delta and the outcrop areas to the west. This sequence consists of a lower shale unit, termed the Boundary Creek Formation, overlain by shales of the Tent Island which is in turn overlain by sands and shales of the Moose Channel Formation.

The Boundary Creek Formation may play a significant role in the subsurface of the Delta because these shales in combination with the overlying Tent Island Formation may provide the source material for a multitude of diapiric structures underlying the Beaufort Sea. This relatively thick sequence is composed of soft incompetent shales that exhibit a high degree of plasticity which might produce flowage, similar to salt, under the extreme pressures created by the thick sedimentary overburden of the Late Cretaceous and Tertiary.

The Boundary Creek Formation is overlain by pro-Delta shales of the Tent Island Formation. Following deposition of Tent Island Marine, deltaic conditions were initiated with the deposition of the Moose Channel Formation. These beds are exposed in the outcrop area west of the Delta, and continue into the subsurface of the Delta where they become the productive reservoirs at the discoveries on Richards Island.

The Moose Channel Formation comprises a mixed environment of thick distributary sandstones alternating with pro-Delta shales. This facies can be expected to extend north and westward from Richards Island into the Beaufort Sea where a greater thickness of sediments is likely.

Thick Delta distributary sandstones of the Moose Channel Formation provide the reservoirs encountered at the Taglu, Mallik and Ivik fields, and probably account for other confidential discoveries such as Niglintgak and Adgo.

TERTIARY – Indicated by Yellow on the **Geological Map.**

(i) **Tertiary**

A very thick Tertiary wedge of sediments exists under the Mackenzie Delta, thickening to the north under the Beaufort Sea. This wedge of gravels, conglomerates and sands, is interpreted to range to about 15,000 feet in the Beaufort Basin. This sequence is postulated to pass from the terrestrial-alluvial facies northward into a marine Delta distributary facies which in turn will pass northward into a pro-Delta shale facies. The position of the Delta at any given time will thus govern the facies present at that particular time.

The hydrocarbon reserves under Richards Island result from the mixed Delta distributary-pro-Delta shale facies. This facies is predicted to continue under the Beaufort Sea and thicken upwards as Tertiary beds pass from the terrestrial deltaic deposits of the mainland to marine Delta distributary deposits in the offshore. This thick succession of distributory sediments when associated with diapirs and structures of large magnitude should provide an exceptionally high hydrocarbons potential throughout the Beaufort Basin.

On northern Richards Island, stacked gas reservoirs have been encountered in each successful well. The thickness of the sandstone bodies is variable, and within the deltaic sequence, the number of such units can also be variable. Initial exploration is directed towards large structural features which can be defined by seismic interpretation. However, good prospects exist for the stratigraphic entrapment of hydrocarbons within locally discontinuous sand bodies of the deltaic system.

A supporting factor for the substantial potential in this area lies in the similarity between this basin and the Gulf Coast basin, both structurally and stratigraphically. It is reasonable to expect that the yield factor for the petroleum potential of the Beaufort-Mackenzie Basin will not be unlike the Gulf of Mexico Coast.

APPENDIX II

TECTONICS AND DEPOSITION

The Mackenzie Delta-Beaufort Sea and area to the south and west of the Delta has been a tectonically active region during much of geologic time. Deposition in this active region differs substantially from the stable craton east of the Mackenzie River and Tuktoyaktuk Peninsula. Depositional basins have occupied the unstable region west of the craton and like the Gulf Coast of the United States, a thick sedimentary wedge occurs with almost continuous deposition throughout the Mesozoic periods.

The unstable basin regions of the Yukon and Northwest Territories appear continuous with the equivalent region in the Arctic Islands which is now occupied by the Sverdrup Basin. Similarities of the sedimentary history of the two basin area indicate a continuation of the Franklinian Geosyncline southward to join the Cordilleran Geosyncline, with a southwest trending branch extending across Northern Alaska.

During Proterozoic, the western regions of the report area subsided deeply, depositing thick Precambrian and Cambrian sediments, mainly shales. To the east, more stable conditions prevailed where a thinner sequence of sands, shales, and carbonates were deposited.

In Middle Cambrian time, most of the **Geological Map** area became relatively stable, with the deposition of carbonates and evaporites. The British Mountains, however, continued to subside through Cambrian time, with the deposition of shales of the Neruokpuk Formation. Stable conditions existed under the Anderson-Horton Plain, where a large evaporite basin developed (Saline River Formation). This basin is postulated to extend eastward through the North Richardson Mountains and may continue northward to provide the source for possible gypsum diapirs under the Beaufort Sea.

During late Cambrian time, a trough began to develop along the craton margin immediately west of the Mackenzie River where thick shales (Road River) were deposited in a narrow belt trending northeast toward the Delta. This trough existed with only minor alterations until late silurian time. During early Devonian time, the report area was emergent, with the exception of a narrow trough where carbonate deposition persisted in the White Mountains near the Yukon–Northwest Territories boundary.

At middle Devonian time, stable marine conditions resumed throughout the area of the Tuktoyaktuk Peninsula, with the deposition of carbonates of Goasage-Ogilvie Formations. To the west, a trough – more or less coincident with the earlier Road River trough – again existed where shales of the Prongs Creek Formation were deposited. Further west in the British Mountains, Middle Devonian beds are absent as this area underwent uplift with associated faulting. Granitic intrusions presently exposed at Mount Fitton and Mount Sedgewick were emplaced. These intrusions are dated Middle and Upper Devonian respectively.

Upper Devonian sedimentation is characterized throughout the area by relatively thick mainly non-marine clastic sediments, indicating rapid subsidence. Later uplift resulted in the removal of these sediments from the southern Delta. A return to carbonate deposition occurred in the area west of the Richardson Mountains during Carboniferous time, with the laying down of the Lisburne Group.

During Permian time, a thick sequence of sands, shales and limestones were deposited, however, much of these sequences have been removed by post-permian erosion. A downwarp of the Richardson trough, during the Jurassic time, resulted in the deposition of thick clastics in the Richardson and British Mountains.

Rapid subsidence of the Delta and regions to the north began early in Mesozoic and continued with deposition of extremely thick shale sequences during Cretaceous time. Deltaic deposition commenced late in tertiary time and continued with deposition of extremely thick sands and shales which may range in thickness up to 25,000 feet in the northern Richards Island area.

Diapirism in the Beafort Sea may have an early origin with growth continuing to the end of Mesozoic. The origin of these features is unknown but may be interpreted either as shale diapirs originating from late Cretaceous, or as salt diapirs originating from the Cambrian or Permian times. Seismic has indicated that there are a great many of these features in the Beaufort Sea region northwest of Richards Island.

APPENDIX III

LAND RATINGS

Although frequent reference is made to the land positions of Imperial Oil, Shell and Gulf, there are other companies in the Delta with acreage holdings. An alphabetical listing and relative rating of the land positions of some of these companies – where information is available – has been prepared. The ratings from "Good" to "Excellent" are based solely on the overall quality of the exposure and probability for discovery. No attempt is made in this rating to indicate the leverage that any probable discovery on a property would have on the particular company. The ratings are also relative to those other companies in the area.

Company	Rating
Bow Valley Industries	Good
Canadian Export Oil and Gas	Good
Canadian Superior Oil	Very Good
Chevron Standard	Good
Dome Petroleum	Very Good
Gulf Oil Canada	Excellent
Hunt Oil Company	Good
Imperial Oil	Excellent
Mobil Oil Canada	Excellent
Numac Oil and Gas	Good
Scurry Rainbow Oil	Good
Shell Canada – Shell Explorer	Excellent
Sun Oil	Good
Union Oil	Good

139° 138° 137° 136° 135° 134° 133° 132° 131° 130° 129°

71°

B E A U F O R T S E A

-600

TEXACO

HUNT (DOME OPTION)

CDN SUPERIOR

DOME

DOME

DOME

HUNT (DOME OPTION)

CDN EXPORT SCURRY SUN

DOME

TEXACO

HUNT

CANADIAN SUPERIOR

WESTERN DECALTA PETROL

CDN EXPORT SCURRY SUN

UNION

CANADIAN SUPERIOR

SIEBENS HUNT

GULF-MOBIL

GULF

GULF-MOBIL

ELF AQUATAINE

TEXACO (DOME OPTION)

B.P. BVI AMOCO ULSTER

IMPERIAL

CHEVRON

RUSSELL INLET

70°

DOME

CDN EXPORT SCURRY

GULF

GULF-MOBIL

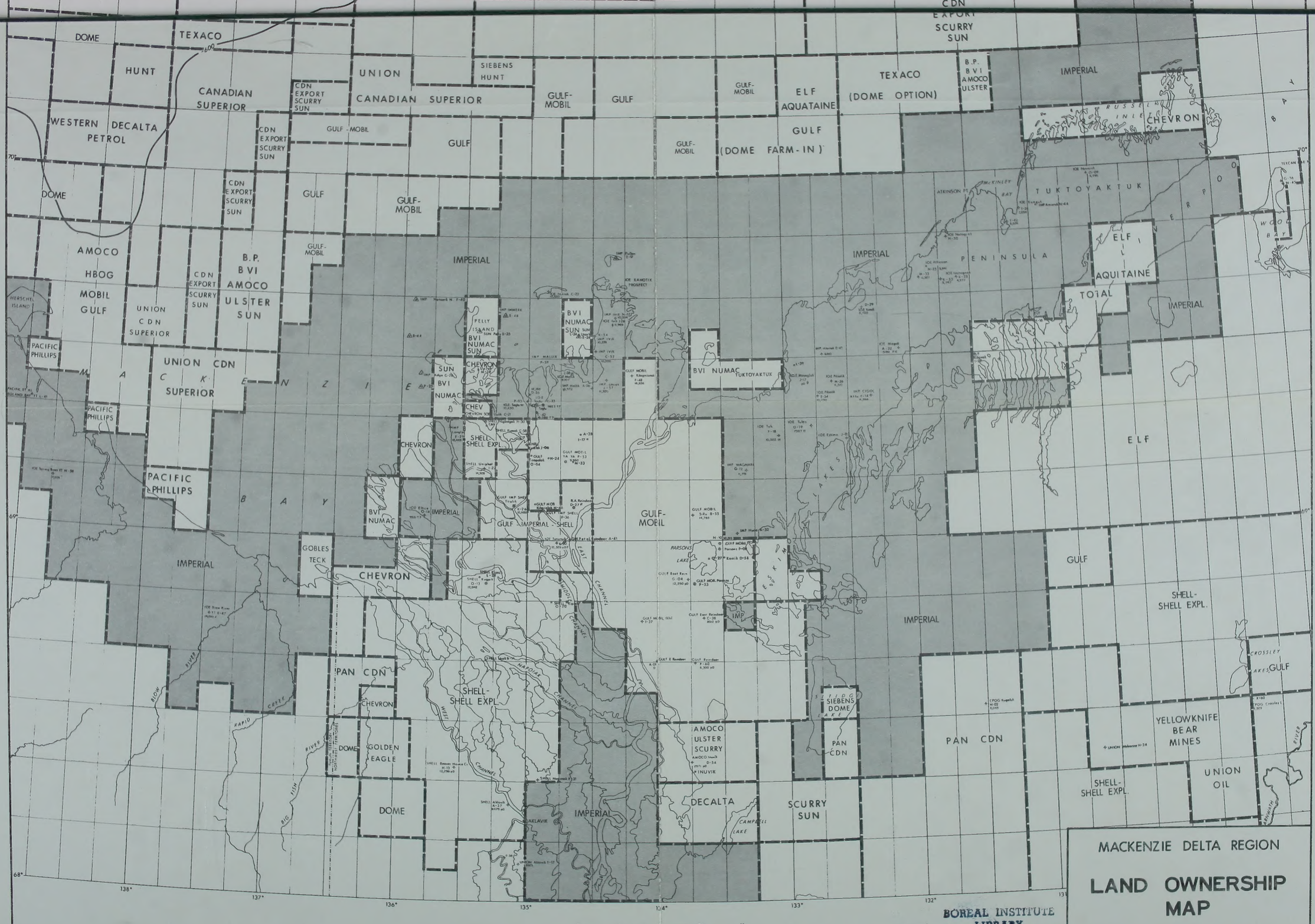
GULF (DOME FARM-IN)

TUKTOYAKTUK

ATKINSON PT.

McKINLEY

B A Y



MACKENZIE DELTA REGION

LAND OWNERSHIP MAP

Date: November, 1974

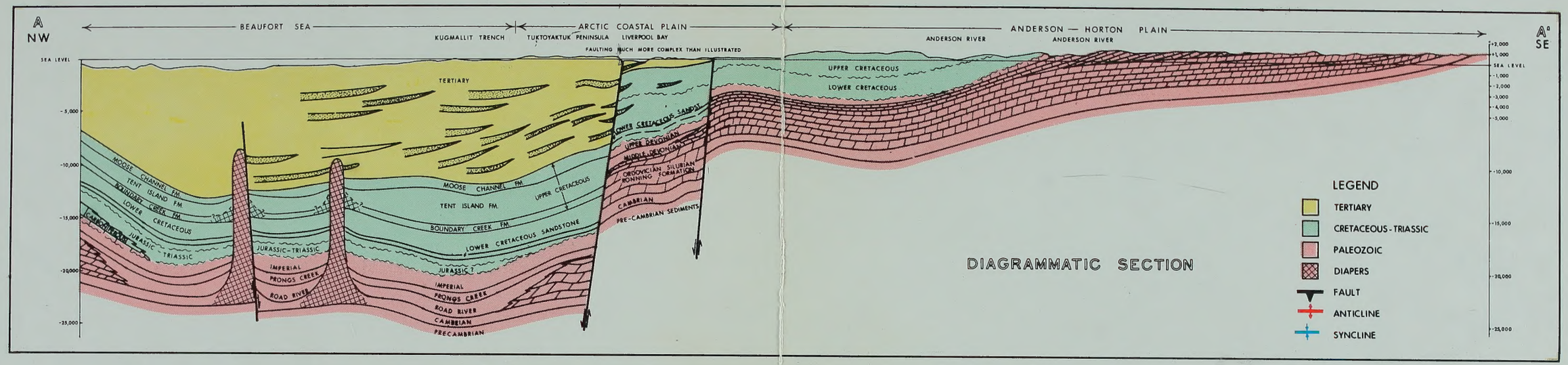
Bathymetry in feet

PRINTED IN CANADA

MACKENZIE DELTA REGION

Prepared For

McLEOD, YOUNG, WEIR & COMPANY LIMITED



MACKENZIE DELTA REGION

GEOLOGICAL MAP

Geology by: L.W. CUMMING P.Geol.
CUMMING EXPLORATION CONSULTANTS LTD.
CALGARY, ALBERTA

Date: November, 1974

Bathymetry in feet

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